Training Program : Point-to-Point Radio Link Design

Course : Introduction & Basics

COMPLEMENTS to Lesson 2 : Basic Radio Link Equation

Useful Antenna formulas

For reflector antennas, the antenna gain g is proportional to the ratio between the antenna diameter D and the wavelength λ :

$$g = \eta \cdot \left(\frac{\pi \cdot D}{\lambda} \right)^2 = \eta \cdot \frac{4\pi \cdot A}{\lambda^2} = \frac{4\pi \cdot A_E}{\lambda^2}$$

where η is called "antenna efficiency" (typically in the range 0.55 - 0.65), A is the reflector area and $A_E = \eta A$ is the Antenna Effective Area (or Aperture).

In logarithmic units :

$$G(dB) = 10 Log_{10}(g) \approx 20 Log_{10}(D) + 20 Log_{10}(F) + 18.2 \pm 0.5$$

where the ±0.5 dB term depends again on antenna efficiency (diameter D is expressed in meters [m] and frequency F in Gigahertz [GHz]).

Again for reflector antennas, a useful "rule of thumb" gives the 3-dB beamwidth BW (in deg) as a function of antenna diameter D [m] and frequency F [GHz] and the gain G [dB] as a function of the 3-dB beamwidth BW [deg] :

$$BW \approx \frac{22}{(F \cdot D)}$$

$$G \approx 45.5 - 20 Log_{10}(BW)$$

More on Free Space Loss

The word "Loss" could suggest some similarity with losses in coaxial cables or other guided transmission of electromagnetic (EM) signals, where we observe an interaction and energy transfer from the EM wave to the propagation medium.

When talking about "Free Space Propagation", we need to consider that the propagation medium is the vacuum and no interaction exists between the EM wave and the medium. The Free Space Loss is just to be referred to the density of EM energy, which follows the "Inverse Square-Law" dependence versus distance from the source.

We conclude that the Free Space Loss is a convenient step in evaluating the received power in a radio link and it is useful in order to put formulas in a manageable form. However, care should be paid about the physical concept related to it, in order to avoid misleading interpretations.

Hops with a Passive Repeater

When a Passive Repeater is used in a radio hop, we have to revise the "Basic Radio Link Equation". A simple "mirror" repeater is implemented as a metal surface, which is close to a 100% reflection efficiency.

Note that the useful or "effective" area A_E of the plane reflector is given by :

$$A_E = A_{REAL} \cdot \cos(\varphi / 2)$$

where A_{REAL} is the real reflector area and φ is the angle between the two rays.

To be consistent with the Free Space Radio Link Equation, the new equation is :

$$P_R = P_T + G_T + G_R - FSL(D_{TOT}) - L_{PR}$$

with : $FSL(D_{TOT})$ is the Free Space Loss of a radio link with path length $D_{TOT} = D_1 + D_2$

D_1, D_2 are the lengths of each "semi-hop", from one hop terminal to the mirror;

L_{PR} is the additional passive repeater loss, in comparison with Free Space case:

$$L_{PR} = 49.54 + 20Log_{10}\frac{D_1 \cdot D_2}{D_1 + D_2} - 20Log_{10}(F \cdot A_E)$$

where F is the working frequency in GHz and D_1, D_2 are expressed in km.

It easy to check that the expression $(D_1 \cdot D_2) / (D_1 + D_2)$ maximizes when $D_1 = D_2$, that is when the mirror position is in the middle of the hop. Therefore, it is advisable to put the mirror rather close to one terminal site in order to reduce the repeater loss.

However, it should be noted that the above formulas are not applicable if the mirror is in Near Field of one terminal antenna, that is where the antenna diagram is not yet stabilized and the electromagnetic (EM) field cannot be approximated as a plane wave.

Useful References

[1] ITU-R Rec. P.341-7, The concept of transmission loss for radio links, 2019

[2] ITU-R Rec. P.525-4, Calculation of free-space attenuation, 2019